Acid and base balance disturbances

- By
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- **Amother of 3-children died from water intoxication after a radio station drinking competition.**

  One of her colleagues said: she said that she was on her way home with severe headache. She was crying and that was the last that anyone had heard from her. Her body was discovered at her home on Friday.

  - What about distribution of water in the body?
  - What is osmosis?
  - What we mean by the term isotonic solution? Give examples?
  - What we mean by the term hypotonic solution? Give examples?
  - What we mean by the term hypertonic solution? Give examples?
  - From your biochemical knowledge, How you can explain this case?

REMEMBER THAT

- The severe hyponatraemia decreased her plasma osmolality. The cell membranes are highly permeable to water but relatively impermeable even to small ions like sodium and chloride. So. In acute hyponatraemia water will move rapidly into cells. Including brain cells. And cause them to swell. *Because the brain is incased in a solid vault.* Oedema of the brain will compress the blood vessels causing cerebral *hypoxia* which is the cause of headache, seizures & other complications. If the *cerebral oedema* is unresolved. It will kill the patient.

- A 20-years-old man was admitted to hospital after a seizure at home. He had ingested one tablet of ecstasy 6 hours prior to the onset of the seizures. He had consumed a large volume of water along with the ecstasy tablet.

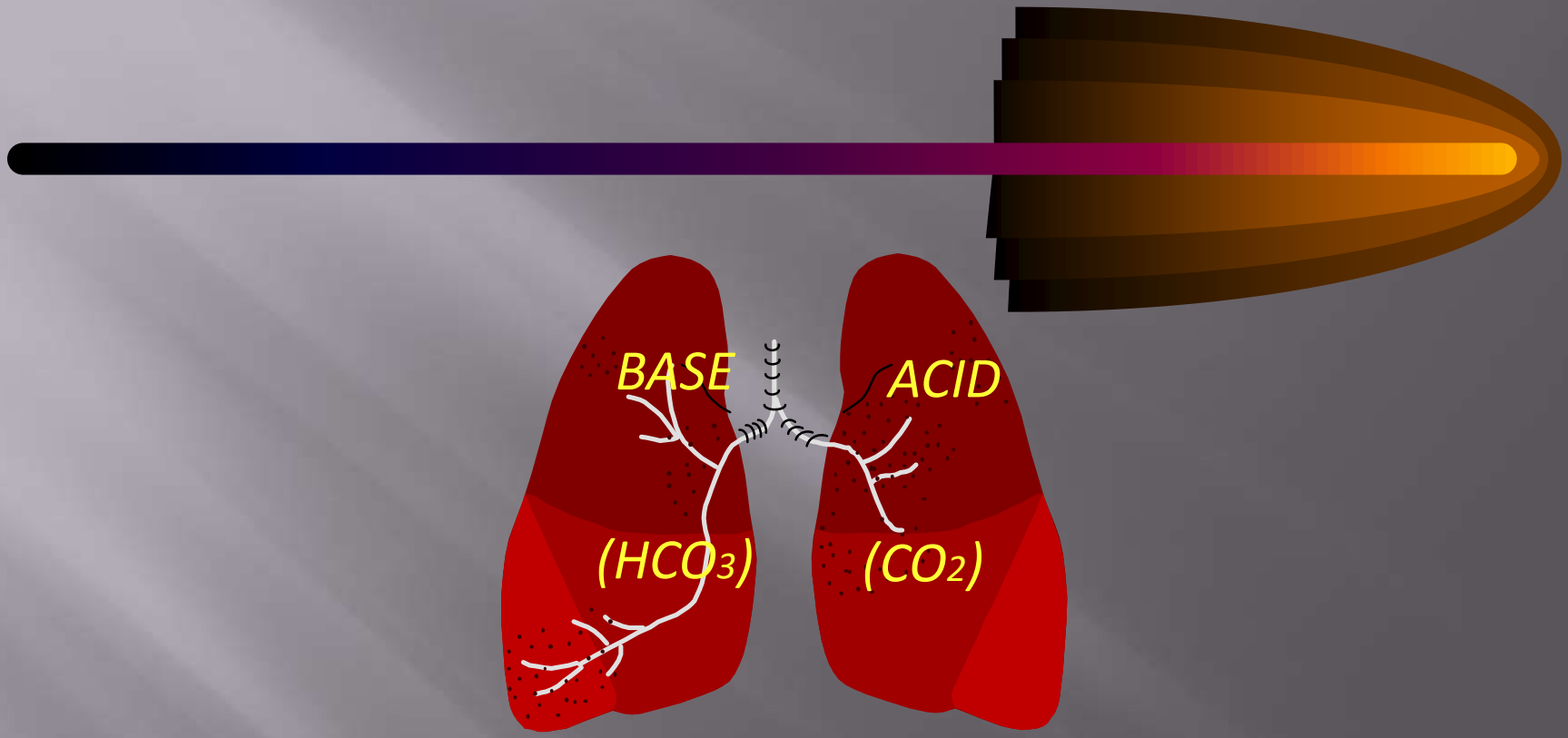
- Investigation showed a serum sodium of 101 mmol/l
- Low serum osmolality.

- In the emergency room he suffered generalized tonic-clonic seizure. The chest x-ray showed widespread opacification of both lungs consistent with pulmonary edema.
- The patient was given sodium chloride to restore the sodium level back to normal. There was no recurrence of seizures and the pulmonary oedema resolved.
- What about distribution of water in the body?
- What is osmosis?
- What is isotonic solution? Give examples?
- What is hypotonic solution? Give examples?
- What is hypertonic solution? Give examples?
- What is the cause of his seizures?

REMEMBER THAT

- The severe hyponatraemia decreased the plasma osmolality. The cell membranes are highly permeable to water but relatively impermeable even to small ions like sodium and chloride. So. In acute hyponatraemia water will move rapidly into cells. Including brain cells. And cause them to swell. *Because the brain is incased in a solid vault.* Oedema of the brain will compress the blood vessels causing cerebral *hypoxia* which is the cause of seizures. If the *cerebral oedema* is unresolved. It will kill the patient.

Acid- base balance



- **Acid** A substance that dissociates in water to produce hydrogen ions (H+). A strong acid almost completely dissociates to produce H+

Hydrochloric acid HCl → H+ + CI-

whilst a weak acid shows poor dissociation and produces relatively few H+

Acetic acid $CH_3COOH \leftrightarrows H+ + CH_3COO-$

- **Base** A substance that can accept H +. In the previous example the chloride ion (CI) is a weak base because it hardly combines with H+ in water, while the acetate ion (CH_3COO^-) is acting as a strong conjugate base because it remains largely associated with H.+

- **Buffer** A mixture of a weak acid and its conjugate base that attenuates a change in H+ concentration when a strong acid or base is added

BLOOD pH

- *Maintained within narrow limits*
- *pH 7.35 to 7.45*

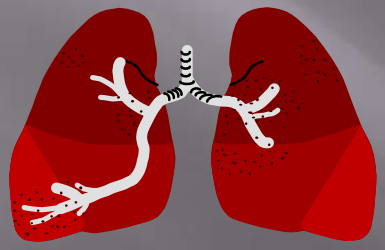
⬆ *pH = Alkalaemia (Alkalosis)*

⬇ *pH = Acidaemia (Acidosis)*

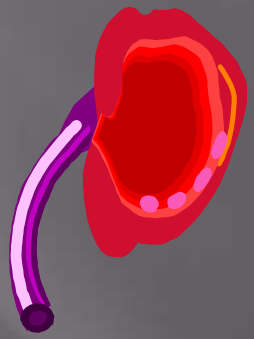
HYDROGEN ION SOURCES

- CO_2 15000 mmol/day

$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$



- Noncarbonic acids 70 mmol/day



Acid-BASE BALANCE

- The pH of the extracellular fluid ranges from 7.35-7.45
- Arterial blood is slightly more alkaline than venous blood :
- Arterial blood pH = 7.40 and venous blood pH = 7.37.
- The pH = negative logarithm of hydrogen ion concentration (H+) i.e. pH = -log (H+).

Henderson – Hasselbalch equation

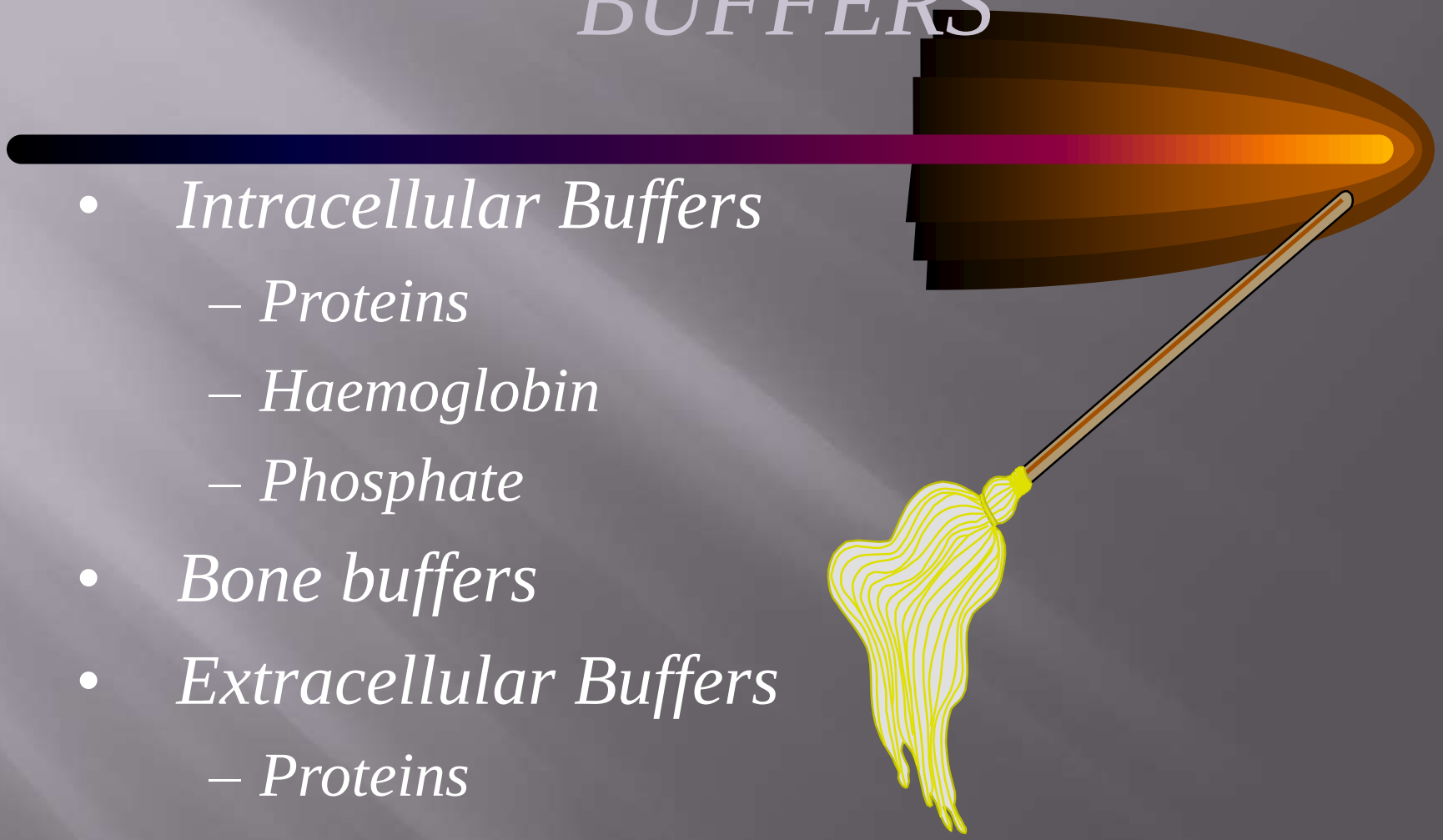
- When H+ is produced during metabolic processes it is buffered by the alkali reserve ($NaHCO_3$) to produce H_2CO_3.
- *The $pH = PK + \log \frac{(HCO_3^-)}{(H_2CO_3)}$ *where PK = 6.1*
- At normal pH (7.4) the log $\frac{(HCO_3^-)}{(H_2CO_3)}$ *must be 1.3*

pH = 6.1+ 1.3 = 7.4

- When interpreting acid-base studies in patients it can be useful to memorize the equation simply as the relationship

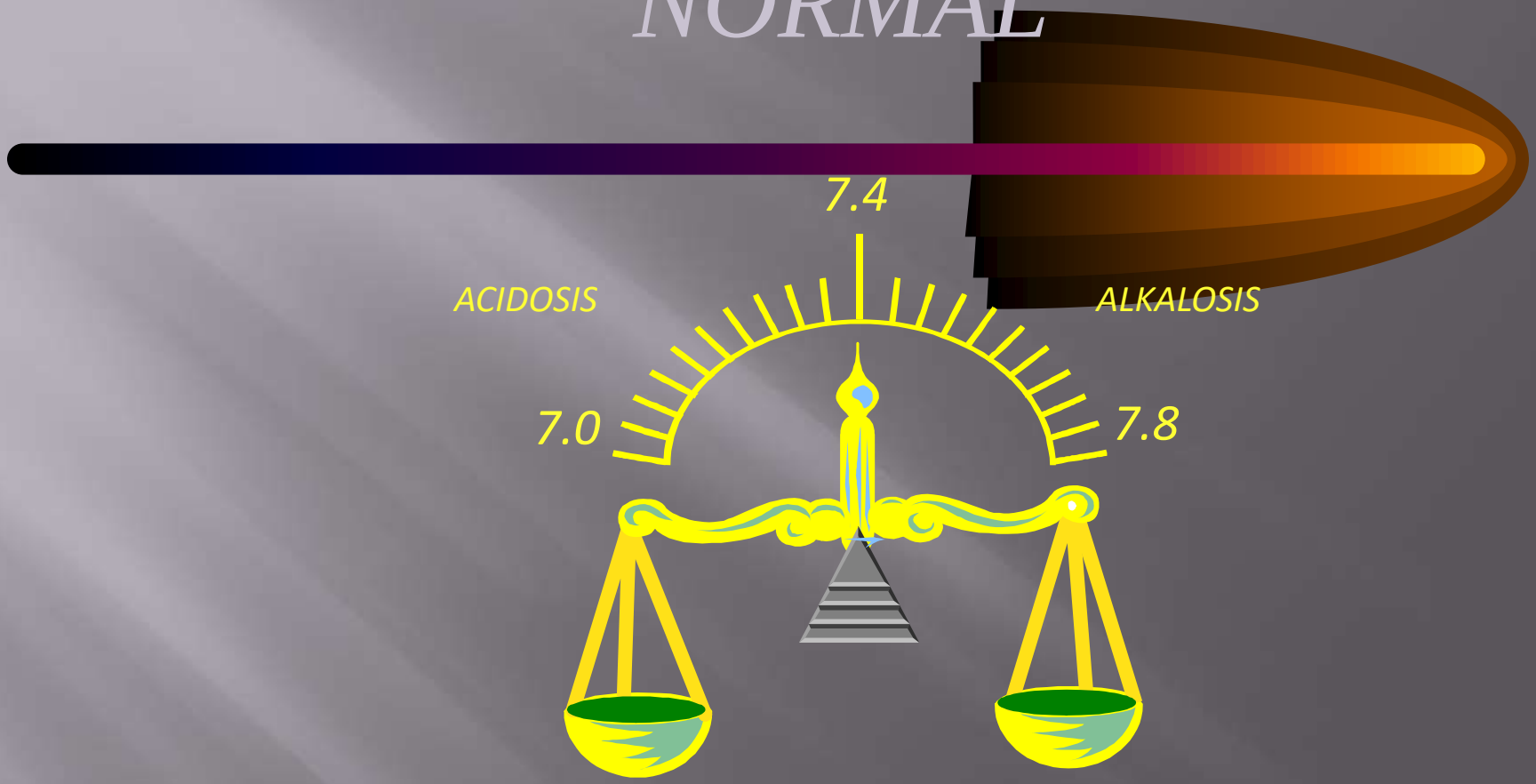
- $pH \propto \frac{[HCO_3^-}{Pco2}$

BUFFERS



- *Intracellular Buffers*
  - *Proteins*
  - *Haemoglobin*
  - *Phosphate*
- *Bone buffers*
- *Extracellular Buffers*
  - *Proteins*
  - *Phosphate*
  - *Bicarbonate*

NORMAL



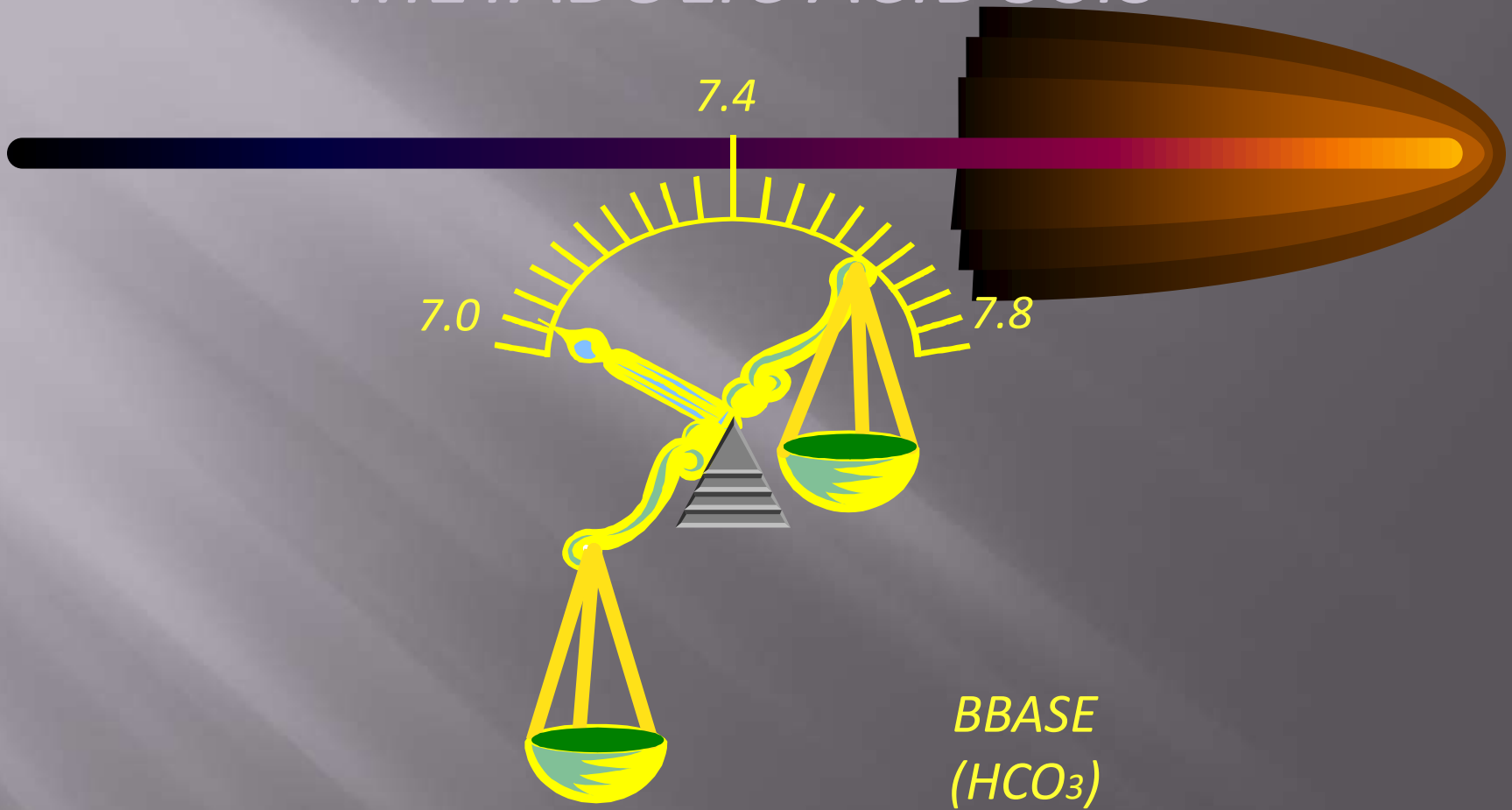
ACID
(CO_2)

BASE
HCO_3

RESPIRATORY COMPONENT

METABOLIC COMPONENT

METABOLIC ACIDOSIS



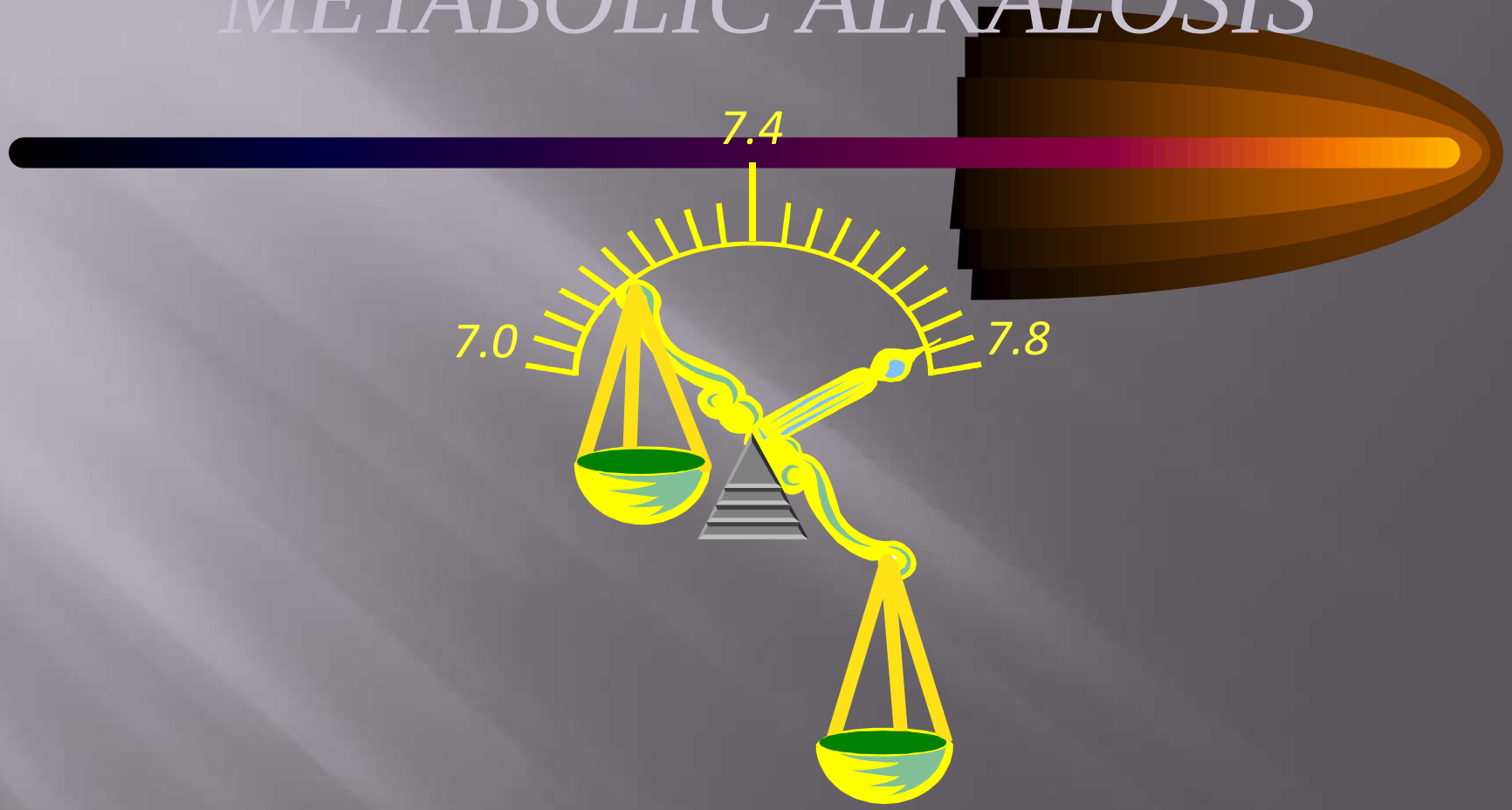
BBASE
(HCO_3)

ACID
(CO_2)

RESPIRATORY COMPONENT

METABOLIC COMPONENT

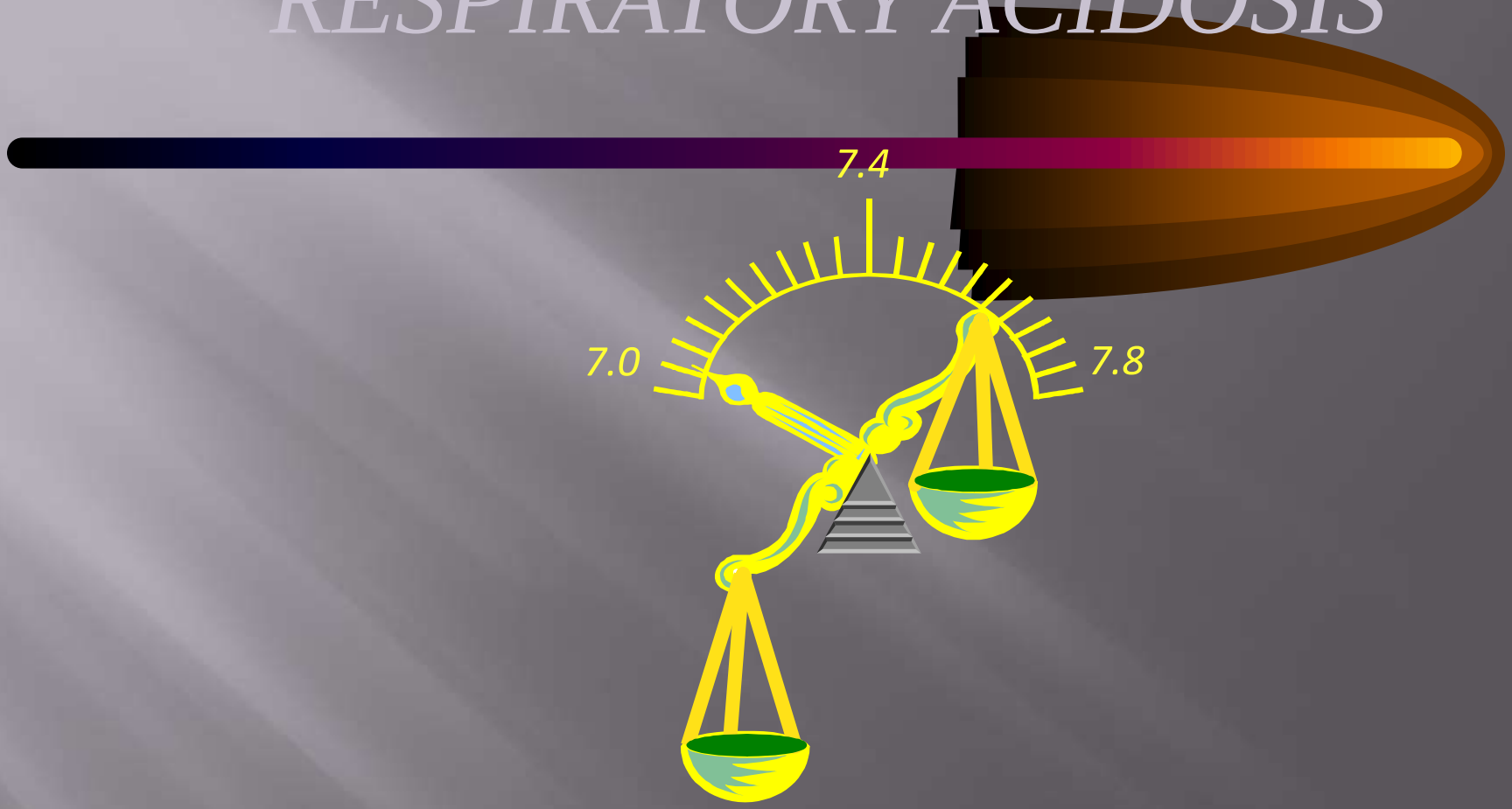
METABOLIC ALKALOSIS



ACID
(CO_2)
RESPIRATORY COMPONENT

BASE
(HCO_3)
METABOLIC COMPONENT

RESPIRATORY ACIDOSIS



ACID
(CO_2)

RESPIRATORY COMPONENT

BASE
(HCO_3)

METABOLIC COMPONENT

RESPIRATORY ALKALOSIS

ACID
(CO_2)

RESPIRATORY COMPONENT

BASE
(HCO_3)

METABOLIC COMPONENT

Ist -senario

- **An 18 years old girl complained of tiredness and weight loss over few weeks . One morning , she felt too ill , developed vomiting and become drowsy . Her room mate called the ambulance. In the A & E department .she was found to have BP95/65,pulse 110/min and cold extremities .She had deep sighing respiration and her breath smelt of acetone .**
- Blood gas measurements :

pH	7.04 (7.35 _ 7.45)
PCO2	2.6kPa (4_ 6)
Bicarbonate	14 (20_30)

- What is acid? & What is base? (definitions)
- What is pH?
- What is acidosis? & What is alkalosis?
- What is buffers?
- From your biochemical knowledge, How you can explain this case?

REMEMBER THAT

- This lady suffers from attack of diabetic kitoacidosis. patient with uncontrolled type-1-DM can develop DKA which is characterized by production of large amount of ketoacids(also called ketone bodies). These are strong acids which dissociate and release H ions. The body buffers will react with H ions and this is why their concentration in blood will drop.
- The metabolic acidosis will stimulate the respiratory center leading to hyperventilation which will help clearing CO2. so the body will get rid of acid that way. The loss of CO2 by ventilation will cause the PCO2 to decrease as well.
- At the same time there will be increased acid secretion in urine to help the body to get rid of the excess acids. so, in metabolic acidosis: there is low pH, low bicarbonates, low PCO2 and increased acid excretion in urine.

2nd -scenario

- **A 39 year old lady presented to the ER with severe vomiting .Physical examination showed tachycardia and hypotension.**
- Blood gas measurements :

pH	7.54 (7.35_ 7.45)
PCO2	6.2kPa (4_6)
Bicarbonate	35 (20_ 30)

- What is acid? & What is base?
- What is pH?
- What is acidosis? & What is alkalosis?
- What is buffer?
- Based on history, likely acid base disorders in this patient are?
- What is the process?

REMEMBER THAT

- Severe vomiting leads to loss of acid and increased production of bicarbonates, causing alkalosis (the mechanism of increased bicarbonate production will be discussed in physiology). So this patient has arised pH and raised bicarbonates level.
- The PCO2 is raised as well as acompensatory measure because metabolic alkalosis is associated with decreased ventilation which leads to retention of CO2 and there for raise PCO2 in the blood.

3rd -scenario

- A 44 year old moderately dehydrated man was admitted with a two day history of acute severe diarrhea.
- Electrolyte results:

Na+	134
K+	2.9
HCO3-	16.

ABG:

pH	7.31
pCO2	33 mmHg (35-45mmHg)

- What is acid? & What is base?
- What is pH?
- What is acidosis? & What is alkalosis?
- What is buffer?
- Based on history, likely acid base disorders in this patient are?
- What is the process?

4th -senario

- **A 70 year old man with history of CHF presents with increased shortness of breath and leg swelling.**

ABG:

pH	7.24
PCO2	60 mmHg(35-45mmHg)
PO2	52
HCO3	27

- What is acid? & What is base?
- What is pH?
- What is acidosis? & What is alkalosis?
- What is buffer?
- Based on history, likely acid base disorders in this patient are?
- What is the process?